PB89-134803

Recovery of DDT, Kepone, and Permethrin Added to Soil and Sediment Suspensions Incubated under Controlled Redox Potential and pH Conditions (Journal Version)

Louisiana State Univ., Baton Rouge

Prepared for

Environmental Research Lab., Athens, GA

1984

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1. REPORT NO.	2.	3. PB89-134803
EPA/600/J-84/415		

4. TITLE AND SUBTITLE	5. REPORT DATE
THE RECOVERY OF DDT, KEPONE, AND PERMETHRIN ADDED TO SOIL AND SEDIMENT SUSPENSIONS INCUBATED UNDER CONTROLLED REDOX POTENTIAL AND pH CONDITIONS (Journal Version)	1984
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Robert P. Gambrell, C.N. Reddy, Vicki Collard, Gloria Green, and William H. Patrick, Jr.	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Center for Wetland Resources Louisiana State University Baton Rouge LA 70803-7511	10. PROGRAM ELEMENT NO. ABWD1A
	11. CONTRACT/GRANT NO. CR804940
12. SPONSORING AGENCY NAME AND ADDRESS Environmental Research Laboratory - Athens, GA Office of Research and Development U.S. Environmental Protection Agency Athens GA 30613-7799	13. TYPE OF REPORT AND PERIOD COVERED
	14. SPONSORING AGENCY CODE EPA/600/01

15. SUPPLEMENTARY NOTES

Journal Water Pollution Control Federation. 56(2):174-182, February 1984

16. ABSTRACT

This study demonstrated that pH and oxidation-reduction conditions affect the persistence of pesticide compounds and that different compounds may respond differently to a given physicochemical environment. The stability of one compound was little affected by altered pH and oxidation conditions, another was markedly affected by oxidation conditions, and the degradation of the third was strongly influenced by both pH and redox potential conditions. The mechanism by which pH or redox potential affected the degradation of two of the three pesticides studied was not determined. It could have involved purely chemical processes. The effect also could be secondary through the influence of physicochemical conditions on the population and activity of microorganisms present and the subsequent metabolic action of these microbes on the compounds. A combination of these processes also could have been involved. Information on the effects of physicochemical conditions on the adsorption and degradation of specific pesticides should contribute to improved predictive capability concerning the fate of pesticide residues in various compartments of the environment.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

REPRODUCED BY
U.S. DEPARTMENT OF COMMERCE
NATIONAL TECHNICAL INFORMATION SERVICE
SPRINGFIELD, VA. 22161

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS (This Report)	21. NO. OF PAGES
RELEASE TO PUBLIC	UNCLASSIFIED	10
	20. SECURITY CLASS (This page) UNCLASSIFIED	22. PRICE

EPA/600/J-84/415
JOURNAL ARTICLE

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This research was conducted to determine the effects of physical and chemical (physicochemical) conditions on the persistence of three insecticides in soil and sediment-water systems. Soil and sediment suspensions were incubated at selected pH and redox potential levels that included the range commonly found in these systems.

Because of the substantial amount of environmental research on pesticides, and especially on insecticides, much is known about their fate and mobility under certain environmental conditions. Most environmental studies on fate and transport focus on well-drained agricultural soils. Pesticide residues, however, are subject to a wide range of physicochemical conditions in the environment. Soon after typical agricultural applications, most residues become associated with medium-textured, well-oxidized, near-neutral pH soils. Subsequently, these residues may be transported in dissolved or adsorbed forms to surface waters and sediments of streams, rivers, lakes, or estuaries where the physicochemical properties, as well as the biological populations of the receiving environment, are very different from the conditions at the point of application.

The persistence and fate of organic pesticides, and thus their environmental impact, differs widely under various physicochemical conditions.

For example, typical agricultural soils exhibit a wide range of texture (from sandy to heavy clay material), pH commonly ranges from 5 to 7.5, and soils are usually nonsaline. Also, the organic carbon content of the plow layer typically ranges from a few tenths of a percent up to a few percent, but normally is less than that of the organic carbon content of sediments in the area. Compared to typical agricultural soils, sediments with which residues become associated are often characterized by finer texture (greater clay content), a narrower pH range (6.5 to 7.5), greater organic carbon content, moderate to strongly reducing (anoxic) conditions, and, depending on coastal proximity, sediments may have a higher salinity.

Sufficient published information is available on pH and oxidation reduction condition effects on degradation for selected pesticide compounds to document that these are important considerations in understanding the environmental fate of many pesticides.[3] However, much more work is needed under carefully controlled pH and redox potential conditions to improve understanding of factors affecting the environmental persistence and transport of pesticides. This is especially important because little is known of the physicochemical effects on the fate of most pesticide residues in certain environmental compartments, such as sediment-water systems where residues have the greatest potential for biological accumulation and subsequent adverse effects.

Three insecticides were studied. DDT [1,1-bis-(p-chlorophenyl)-2,2,2-trichloroethane] was included because it is still widely distributed in the environment, although its use has been greatly reduced in recent years. This compound was incubated with a Mobile Bay sediment material; most published information on DDT degradation involves soil materials. The Mobile Bay sediment material used contains substantially more clay and organics than typical agricultural surface soils, especially those in the Southeast. Samples were also analyzed for DDD [1,1-bis-(p-chlorophenyl)-2,2-dichloroethanel and DDE [1,1-bis-(p-chlorophenyl)-2,2-dichloroethylene].

Kepone [decachloro octahydro-1,3,4-metheno-2H-cyclobuta[cd]-pentalene-2-one] is associated with known environmental problems that are confined to the James River and connecting estuary. Essentially nothing was known of the factors affecting Kepone persistence in soils and sediment-water systems, therefore, this compound was included in the hope that the results might suggest something about the fate of kepone in the James River and perhaps suggest management practices that could be used to minimize possible adverse environmental impacts.

The persistence of Permethrin [3-phenoxybenzyl (±) *cis-trans*-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropanecarboxylate], is a synthetic pyrethroid. The synthetic pyrethroids are a relatively new class of insecticides that are highly effective against target insects, exhibit low mammalian toxicity, and are far less persistent in the environment than many chlorinated hydrocarbon insecticides. The high susceptibility of larval and juvenile crustaceans to certain of these compounds[8] and the expected increase in importance of the synthetic pyrethroids in insect control programs suggest that it is important to examine factors affecting the persistence of these residues in the aquatic environment.

MATERIALS AND METHODS

Experimental microcosms. Pesticide-amended soil and sediment suspensions were incubated under controlled pH and

redox potential conditions using the microcosm assembly shown in Figure 1. Suspensions were maintained in the 2-L, 3-necked, flat-bottomed flasks by continuous stirring of the soil- or sediment-water mixture using a motor-driven magnetic stirrer. Flexible polyvinyl chloride (PVC) tubing was placed over the 5.08-cm teflon-coated magnetic stirring bar in each flask to prevent abrasive wear to the stirring bar. Each flask was equipped with a combination pH electrode, two platinum electrodes for monitoring redox potential, a thermometer, a serum cap for adjusting pH or extracting samples, separate inlet tubes for air and nitrogen, and an outlet tube, the end of which was submerged in a water trap to prevent gaseous oxygen diffusion into the flask. The two bright platinum electrodes positioned in the sediment suspension were connected to a millivolt/pH meter for redox potential monitoring and control. A saturated calomel reference electrode was connected to the suspension with a saturated potassium chloride-agar salt bridge. The recorder output of the millivolt/pH meter was connected to a meter relay, which switched on an aquarium-type air pump whenever the redox potential dropped below the present level for each incubation flask. Slow oxidation of the suspension during the aeration cycle was achieved by metering the air flow to about 1 to 4 mL/min. When the redox potential again reached the preset potential, the meter relay automatically switched off the air pump.

Oxygen-free nitrogen gas was continuously supplied to the suspension at a rate of about 5 mL/min. through a separate gas inlet. This nitrogen gas removed air contamination from possible small leaks in the system, prevented an accumulation of gaseous decomposition products such as carbon dioxide or hydrogen sulfide, which might affect microbial activity, and purged excess oxygen from the system at the end of the aeration cycle. This system permits controls redox potential to within 5 to 10 mV of the desired potential.

Suspension pH was checked once or twice daily and adjusted using a syringe to add 1N hydrochloric acid or 1N sodium hydroxide through the serum cap in the center rubber stopper. The combination pH electrodes used required infrequent recalibration. The reference electrode portion, equipped with an annular ceramic reference junction, was not significantly affected by gradually changing junction potential attributable to clogging by colloidal particulates. All suspensions were maintained at 28°C ± 1°.

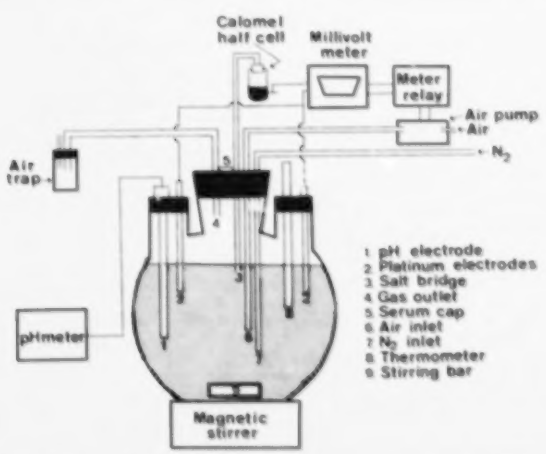

Figure 1—pH and redox potential control apparatus for incubating pesticide-amended soil and sediment suspensions.

Soil and sediment materials were batched when initially received and then separated into smaller glass or plastic-lined metal containers for storage at 4°C in their natural moist or saturated conditions until needed in laboratory incubation studies. Each small storage container was thoroughly mixed on a roller-mixer immediately prior to being weighed out into the incubation flasks. Sufficient water was added to adjust the solids-to-solution ratio (300 g soil or sediment solids, on an oven dry basis, plus 1 500 grams of water), and stirred to begin preliminary incubation. The preliminary incubation consisted of gradually adjusting both pH and redox potential conditions of the suspension in each vessel to preselected levels. Seven to 10 days were usually required to achieve these. This was followed by an additional 4 to 7 day equilibration at the treatment pH and redox potential levels before the suspensions were amended with pesticides. Samples were obtained from the flasks by withdrawing suspension aliquots from the incubation flasks with a 50-mL glass syringe equipped with a 12-gauge, stainless steel needle. The sample aliquots were placed in 112-mL (4-oz) glass bottles for further processing. If the samples were to be stored before extraction, an aluminum foil-lined cap was fitted on the glass bottle and the sample placed in a freezer until needed for extraction and analysis.

Soil and sediment sample extraction. All work with DDT used Mobile Bay (Alabama) sediment material. The sampling location (near Buoy #38) was about 800 m east of the Mobile Bay ship channel and 8 to 9 km south of the main harbor area of Mobile. For DDT, the samples were thawed and centrifuged in their glass storage bottles and the aqueous phase discarded. Acetone was shaken with the residual sediment and the mixture was centrifuged. The acetone supernatant layer was saved and this procedure repeated to remove excess water from the sediment phase. The residual acetone was evaporated, the sediment sample was ground and a portion weighed into Soxhlet thimbles. The sediment sample was extracted for 12 hours on the Soxhlet apparatus using 130 mL of a 3:1 hexane:acetone mixture. After Soxhlet extraction, the acetone rinses from the drying step were combined with the Soxhlet extraction solvent in a separatory funnel, the contents were shaken and allowed to separate. The aqueous layer was drained and discarded. This procedure was done three times to remove the acetone. The hexane extract was poured through sodium sulfate and then made to volume or diluted as necessary for analysis by gas chromatography.

Studies of Kepone persistence under controlled physicochemical conditions were conducted using sediment material taken from a mud flat/marsh grass area adjacent to Bailey's Creek near Hopewell, Virginia. This is part of the area affected by Kepone contamination from the Life Science Kepone manufacturing plant located in Hopewell, James River sediment material, which was incubated as a suspension at selected pH and redox potential conditions, was amended with a solid Kepone spiking material. This material was prepared by grinding 37.5 mg of Kepone (99% purity, pesticide standard grade material) with 30 g of a silty loam soil that had been combusted at 900°C to destroy organic matter. Five g of this Kepone-amended soil material containing 6.25 mg Kepone was added to each suspension (containing 300 g sediment solids) as an

aqueous slurry (20 mL H_2O) to give a spiking level of about 21 μg/g. Although apparent degradation products of Kepone have been observed on gas chromatograms,[15] during the time of this study the identity of possible Kepone degradation products was unknown, and no standards were available for identification and quantification of degradation products.[11]

The Kepone extraction procedure was similar to that used for DDT except that the solvent used for the 12-hour Soxhlet extraction was a 1:1 benzene-methanol mixture.

Permethrin was studied using aqueous suspensions of an Olivier silty clay loam soil obtained from the Louisiana State University Agricultural Experiment Station Burden Research Center in Baton Rouge. Aqueous suspensions of the Olivier soil material were amended with Permethrin dissolved in acetone.

The Permethrin extraction procedure was also similar to that previously described for DDT, except that a 60:40 hexane:acetone solvent was used with an 8-hour Soxhlet extraction.

The operating conditions for the gas chromatograph are given in Table 1. DDT, DDD, DDE, Kepone, and Permethrin were strongly partitioned with the solid phase, causing dissolved levels in the aqueous phase to be negligible in terms of the total compound present. Thus, physicochemical effects on degradation could be determined by considering the change in DDT levels associated with the solid or sediment phase. Therefore, the solution phase was separated by centrifugation and discarded; only the solid phase (soil or sediment) was extracted. Duplicate samples were processed for Kepone and Permethrin, but only for about half of the DDT samples. This represents subsampling, not replication of experimental units. Figure 2 indicates the levels of DDT recovered with time from two separate incubations of DDT at pH 8.0 and +50 mV. The method of drying samples from these two incubations differed, but subsequent work indicated that the drying methods did not affect DDT recovery.[4] Therefore, the closeness of data points from these separate incubations indicates that the experimental laboratory microcosms replicated reasonably well.

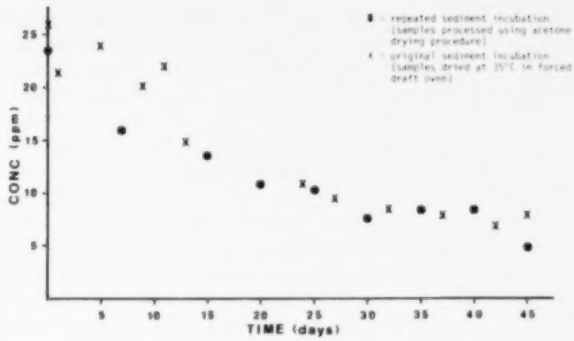

Figure 2—DDT recovery with time from two Mobile Bay sediment suspensions incubated at pH 8.0 and +50 mV.

RESULTS AND DISCUSSION

DDT. Each of the three compounds was incubated at three pH levels. Suspension pH seemed to affect the rate of loss of Permethrin, but there was no clear pH effect on the loss of DDT and Kepone. Data for only one pH level are presented for DDT (Figures 2-5) and Kepone (Figure 6). Data for two pH levels are presented for Permethrin (Figures 7 and 8). Complete data are available in a grant completion report.[4]

DDT-amended Mobile Bay sediment material was incubated under mildly acid to mildly alkaline conditions (pH 6.0, 7.0, and 8.0) and four redox potential levels ranging from strongly reduced to well oxidized (−150, 50, 250, and 450 mV) to determine the effect with time on the levels of DDT and its two predominant degradation products, DDD and DDE. The effects of pH on recovery of DDT from the amended sediment material were negligible at each of the four redox potential levels studied. Redox potential treatments, however, greatly affected the recovery of DDT.

Table 1—Operating parameters for gas chromatograph.

	Compound		
Parameter	**DDT (also DDD and DDE)**	**Kepone**	**Permethrin**
Carrier gas	Zero grade N_2	Zero grade N_2	Zero grade N_2
Carrier gas flow rate, mL/min	70	70	70
Sample injected	5 mL	5 mL	5 mL
Injector temperature, °C	225	225	225
Oven temperature, °C	220	220	200
Detector and temperature, °C	ECD, 275	ECD, 275	ECD, 275
Column	6' glass, 10% OV on Chromosorb W, 80/100	6' glass, 1.5% OV-1, 1.95%QF-1, on Chromosorb W, 80/100	6' glass, 5% SP-2330* on Chromosorb W
Reference standards	Health Effects Laboratory U.S. EPA Research Triangle Park, N.C.	Health Effects Laboratory U.S. EPA Research Triangle Park, N.C.	Applied Sciences Laboratory State College, Pa.

* Permits separation of cis and trans isomers of permethrin.

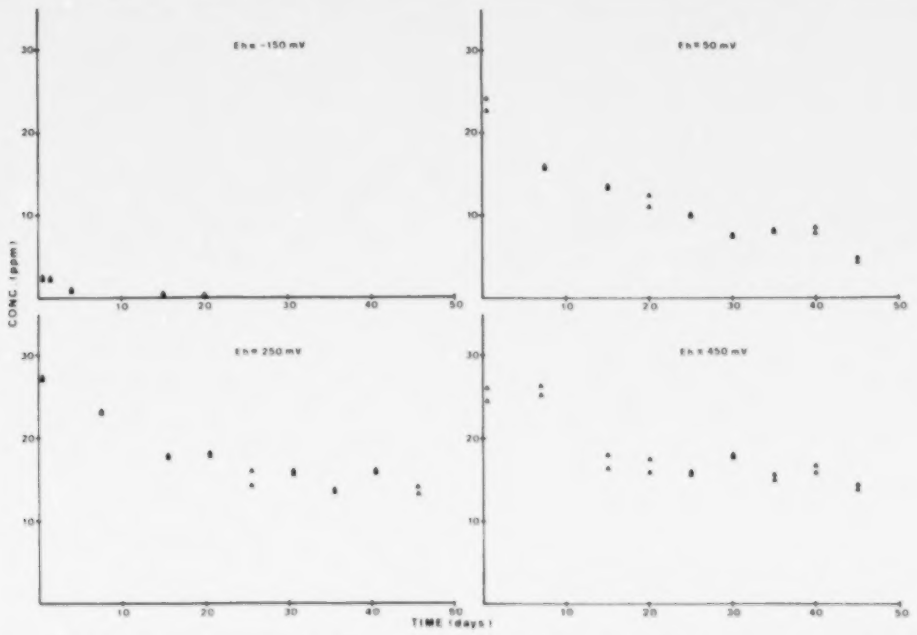

Figure 3—The effect of redox potential (Eh) on the recovery of added DDT from a Mobile Bay sediment suspension amended with DDT during a 45-day incubation at pH 8.0 (amended with 25 ppm DDT initially).

Under well-oxidized and weakly oxidized (+450 and +250 mV) conditions for all three pH levels studied, the recovery of DDT decreased to about two-thirds of initial levels during the first 2 weeks of the incubation (Figure 3). After 2 weeks and until the end of the incubation at about 45 days, DDT recovery remained essentially unchanged or decreased slightly. DDT re-

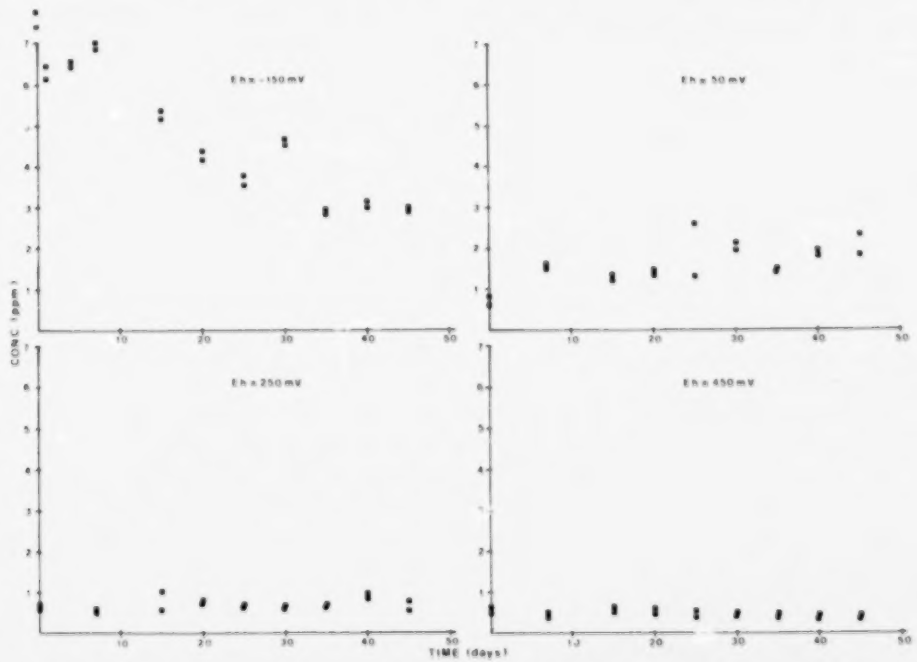

Figure 4—The effect of redox potential (Eh) on the recovery of DDD from a Mobile Bay sediment suspension amended with DDT during a 45-day incubation at pH 8.0.

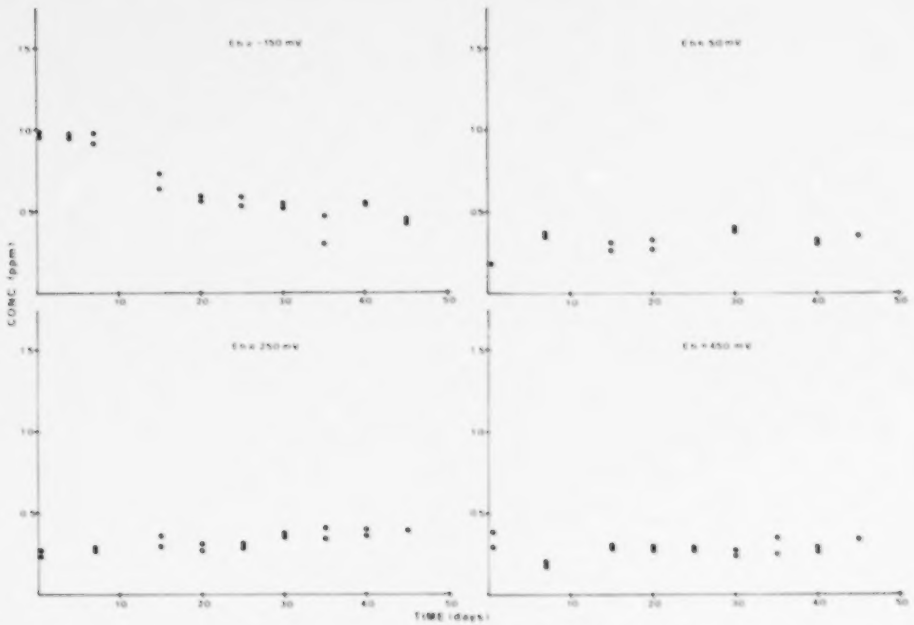

Figure 5—The effect of redox potential (Eh) on the recovery of DDE from a Mobile Bay sediment suspension amended with DDT during a 45-day incubation at pH 8.0.

covery decreased gradually and at an almost uniform rate during the entire incubation under moderately reduced (+50 mV) conditions. Only about one-third of the initial levels were recovered at pH 6.0 and 7.0 and about one-fourth of the initial levels were recovered at pH 8.0 after 45 days. Under strongly reducing conditions (−150 mV), DDT recovery decreased to about 10% of spiking levels within 2 to 5 days, after which recovery approached zero for the duration of the incubation.

Numerous studies[6,7,13] report more rapid degradation of DDT under reducing soil conditions compared to well-drained, ox-

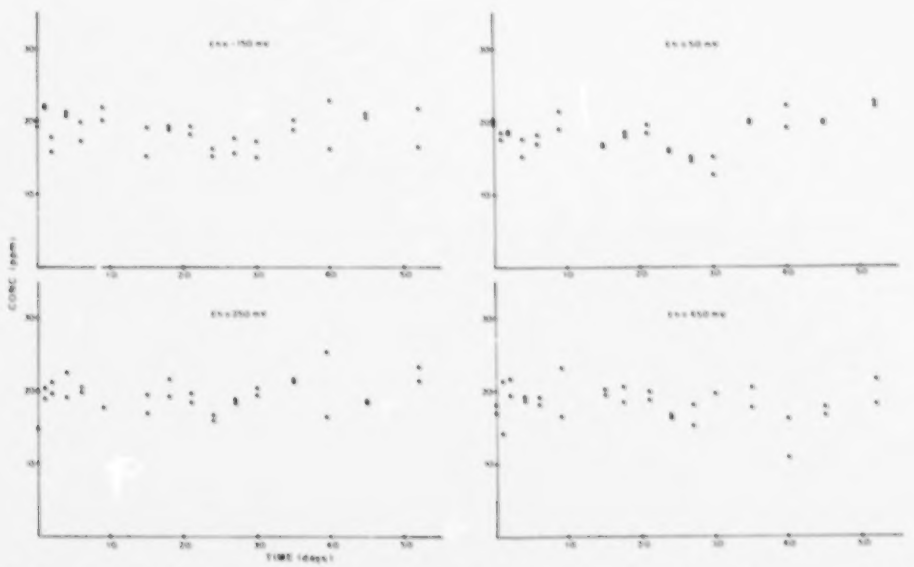

Figure 6—The effect of redox potential (Eh) on the recovery of added Kepone from James River sediment suspension during a 52-day incubation at pH 7.0 (amended with 21 ppm kepone initially).

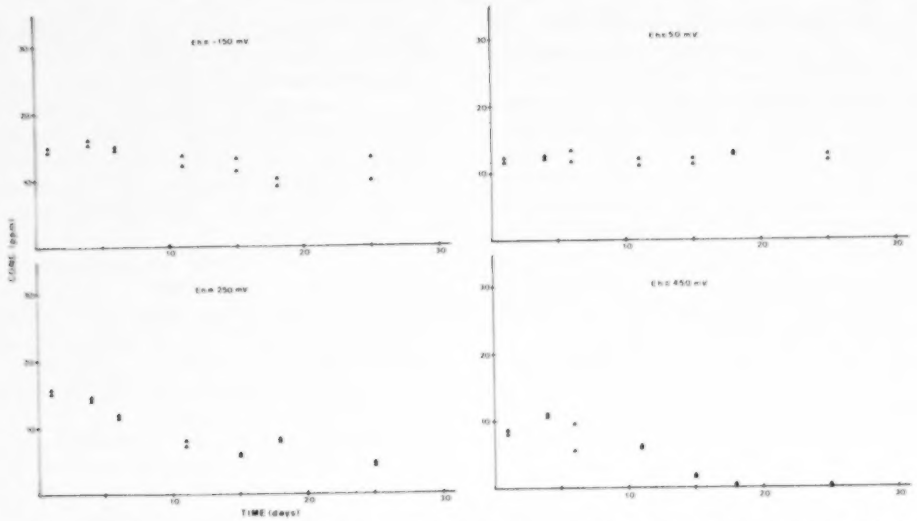

Figure 7—The effect of redox potential (Eh) on the recovery of added Permethrin from an Olivier soil suspension during a 25-day incubation at pH 5.5 (amended with 15–17 ppm Permethrin initially).

idized soils. This apparent rapid degradation (greater than 90% in a few days) at −150 mV warrants additional discussion. Only one other published report of comparable DDT degradation rates was found in the literature, a 50% loss in 24 hours in oxygen-deficient lake waters.[12] Most published reports[6,7,13] indicate equivalent levels of degradation in terms of a few weeks to a few months rather than days. Initially, experimental artifacts were suspected. There are several possible explanations for the initial low recovery of DDT under strongly reduced conditions: (1) drying artifacts, (2) volatilization in the continuous stream of nitrogen that purged the system, (3) the "bound residue effect,"[9] (4) adsorption on the glass walls of the flasks, tubing, electrodes, or the teflon-coated magnetic stirring bar covered with PVC tubing, and (5) unusually rapid degradation of DDT in the strongly reduced Mobile Bay sediment materials. Possibilities 1 and 2 were ruled out experimentally. It seems unlikely that the bound residue effect or adsorption to components of the experimental microcosms would cause such a marked decline in DDT recovery only at −150 mV compared to better oxidized treatments.

The fifth possibility is that the added DDT was indeed degraded within a few days at −150 mV. The chemical and mi-

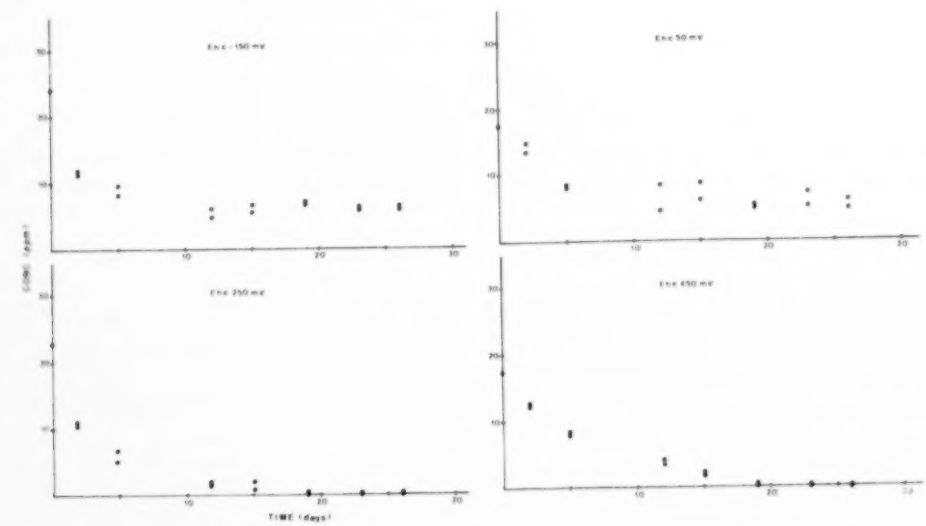

Figure 8—The effect of redox potential (Eh) on the recovery of added Permethrin from an Olivier soil suspension during a 26-day incubation at pH 8.0 (amended with 15–17 ppm Permethrin initially).

crobial properties of the Mobile Bay sediment material at −150 are likely very different from most soil and sediment materials examined in DDT degradation studies, even those studies in which flooded or reduced conditions were imposed. In terms of texture (44% clay, 32% silt) and organic carbon content (1.8%), this material is not atypical of many soil and sediment materials. Its sulfide content, however, at −150 mV was above 400 ppm, potentially reactive iron (that quantity extracted by relatively mild chemical extraction) exceeded 10 000 μg/g and soluble iron levels at −150 mV were 3 600, 330, and 3 ppm at pH conditions of 5, 6.5, and 8, respectively.[2] These properties, and possibly others, make the Mobile Bay sediment material different from most soils used for DDT studies.

Glass[5] concluded that the iron redox system in reduced soils is involved with DDT degradation and that redox systems other than iron may also contribute to DDT reduction by electron transfer processes. A relationship between ferrous iron levels and DDT degradation was established. In that study, the experimental combination of soils and treatments giving most rapid DDT degradation resulted in recovery of only 6% of initial DDT levels after 28 days. Although the extraction procedures for iron in this study differed somewhat from those used by Glass, it has been shown previously that soluble and exchangeable (method similar to the "soluble" iron procedure used by Glass) ferrous iron levels in Mobile Bay sediment material under a range of pH and oxidation-reduction conditions equaled or far exceeded iron levels in the reduced soil materials studied by Glass.[2,5] Therefore, the chemical properties of the Mobile Bay material may be more conducive to rapid DDT degradation than most materials studied and reported in the literature.

An obvious avenue to explore in deciding whether degradation accounted for the rapid loss in DDT is to examine the levels of known DDT degradation products at −150 mV, and especially levels of DDD, because this compound is reported to be the predominant, first-stage decomposition product under reducing conditions.

Although the DDD levels extracted were not sufficient to account for the rapid disappearance of DDT during the first few days, DDD levels in the −150 mV treatment were 3 to 8 ppm during the first few days at all 3 pH levels compared to about 0.5 ppm for the two most oxidized treatments (Figure 4). Thus, there is firm evidence that at least some DDT did degrade very rapidly under strongly reducing conditions, although a mass balance was not obtained. It is possible that some of the DDD rapidly formed was also subject to rapid degradation. Under strongly reducing conditions in Mobile Bay material, another intermediate may have been involved in DDT degradation.

DDE is reported to be the predominant degradation product of DDT under oxidized conditions. DDE levels ranged from essentially zero to around 1 ppm at all pH-redox potential combinations (Figure 5). Surprisingly, based on the literature, the −150 and 50 mV treatments (strongly and moderately reducing) exhibited higher DDE levels than the better oxidizing treatments. Although DDD production was greater than DDE production under the reduced treatments, apparently some DDE was produced under anoxic conditions during the rapid loss of DDT in the Mobile Bay sediment material. Because of the more rapid DDT degradation under reducing conditions, the DDE accumulated to slightly greater levels than in the better oxidized treatments where DDT was relatively stable.

Kepone. Figure 6 indicates the effect of redox potential on the levels of Kepone in James River sediment suspensions incubated at pH 7.0 for 52 days. At all redox potentials, Kepone recovery was 16 to 22 μg/g during the first few days. There was some experimental variability, but no evidence of any reduction in Kepone levels at any redox potential during the 52-day incubation at this pH.

At pH 5.0 and 8.0, there was some evidence of a decrease in Kepone concentrations toward the end of incubation (51 and 70 days, respectively), but any degradation, if it occurred, was masked by experimental variability encountered in the incubation conducted at these two pH levels. At all pH levels, there was no good indication that oxidation-reduction conditions affected Kepone degradation.

Permethrin. A study with Permethrin was conducted using four controlled redox potential levels (−150, +50, +250, and +450 mV) and 3 pH levels (5.5, 7.0, and 8.0). These data for pH 5.5 and 8.0 are presented in Figures 7 and 8.

It is apparent that both pH and redox potential influenced the loss of Permethrin from these systems. Under well-oxidized conditions (+450 mV), Permethrin essentially disappeared (less than 0.5 ppm) at all pH levels after 19 days. Under strongly reducing conditions, approximately one-third was lost from the pH 5.5 treatment, and about two-thirds of initial levels were lost at pH 8.0 after 26 days. In this study Permethrin tended to degrade more quickly with increasing pH under both oxidizing and reducing conditions.

The data in Figures 7 and 8 include the total Permethrin content of the samples (the sum of the cis and trans isomers). Because a gas chromatography column was used that would separate the cis and trans isomers, it was possible to look at the effects of pH and redox potential on the degradation of the individual isomers. Table 2 indicates the percentage of total Permethrin in the trans isomer for two sampling dates under strongly reducing (−150 mV) and well-oxidized (+450 mV) conditions. This information could be calculated for every sample in this study, but Table 2 summarizes the important physicochemical effects. Day 1 (Day 2 for pH 8) was selected to give

Table 2—Effect of pH and oxidation levels on the relative degradation of the cis and trans isomers of Permethrin for selected sampling dates and redox potential treatments.

	Day 1 of incubation (day 2 for pH 8)		Day 15 of incubation (day 14 for pH 7.0)	
pH	−150 mv	+450 mv	−150 mv	+450 mv
	peak height trans/peak height cis + trans, %			
5.5	64.2[a] ± 0.0[b]	62.6 ± 1.5	64.3 ± 0.7	24.4 ± 0.8
7.0	65.7 ± 0.0	62.4 ± 0.1	64.0 ± 0.3	20.0 ± 0.0
8.0	61.6 ± 0.1	56.6 ± 0.1	50.0 ± 0.0	14.8 ± 3.2

[a] Mean of two subsamples (extraction of two separate soil samples from the same experimental incubation vessel).

[b] Standard deviation.

the ratio near the beginning of the incubation. Day 15 (Day 14 for pH 7.0) was selected for inclusion in this table because it was the last sampling date before Permethrin decreased to very low levels in the oxidized treatments.

Table 2 shows that both pH and oxidation have substantial effects on the relative degradation of the cis and trans isomers. Increasing pH (from 7 to 8) and increasing oxidation conditions favored the loss of the trans isomer relative to the cis. There was little change in the ratio under reduced conditions at pH 5.5 and 7.0 during the first 15 days.

In work done elsewhere with treated cotton plot soil, the cis isomer was present in higher concentrations than the trans isomer.[1] It was suggested that either the cis isomer was more persistent or this isomer was more easily removed from treated cotton leaf surfaces and transported to the soil. Surface runoff samples also contained a higher proportion of the applied cis isomer than the trans isomer, and again it was suggested that either greater persistence or mobility of the cis isomer accounted for these differences. This study suggests that soil oxidation conditions probably contributed to enhanced degradation of the trans isomer relative to the cis, because cotton is usually grown in well-oxidized soils.

The results of this study confirm what is already known about Permethrin, that long-term adverse impacts from residues will not pose a problem. This study does indicate, however, that physicochemical conditions of the environmental compartment receiving residues can have a substantial effect on the persistence of Permethrin during the course of a few weeks to a few months. Strongly reducing conditions characteristic of sediments enhance the persistence of Permethrin. This is similar to results for Cypermethrin, another synthetic pyrethroid, which has been found to degrade more quickly under aerobic conditions than waterlogged conditions in a sandy loam soil.[14]

These results also correspond with one study of Permethrin in which approximately 60% of the ^{14}C activity of labelled Permethrin in an oxidized Hagerstown silty clay loam was trapped as ^{14}C-labelled carbon dioxide ($^{14}CO_2$) versus 1% from the anaerobically incubated soil.[10]

SUMMARY AND CONCLUSIONS

The major objective of this work was to examine the effects of pH and redox potential on the degradation of three pesticides. Treatment effects on degradation rates, where noted, should be considered relative; the stirred suspensions at 28°C may favor more rapid transformations than would occur in residues in a typical quiescent soil or sediment-water system. This study demonstrated that pH and oxidation-reduction conditions do affect the persistence of pesticide compounds and that different compounds may respond differently to a given physicochemical environment. The stability of one compound was little affected by altered pH and oxidation conditions, another was markedly affected by oxidation conditions, and the degradation of the third was strongly influenced by both pH and redox potential conditions. It is important to note that changing redox potential levels had opposite effects on DDT and Permethrin degradation.

The mechanism by which pH or redox potential affected the degradation of two of the three insecticides studied was not determined. It could have involved purely chemical processes such as the reaction described by Glass[5] and the iron redox system. The effect could be secondary through the influence of physicochemical conditions on the populations and activity of microorganisms present and the subsequent metabolic action of these microbes on the compounds, or a combination of these processes could have been involved.

Considering the documented high toxicity of certain synthetic pyrethroids to a number of aquatic and benthic organisms,[8] it should be kept in mind that the strongly reduced environs of many sensitive benthic species favor some increase in the persistence of residues that may adversely affect these populations should residues be transported from adjacent fields in surface runoff. On the other hand, residues in upland soils will degrade more quickly. Thus, the length of time between Permethrin application and a significant runoff event will strongly influence the potential for adverse environmental effects of Permethrin residues in wetlands or sediment-water systems.

The ranges of physicochemical (pH and redox potential) parameters studied are commonly encountered in soils, sediments, and surface water that may receive pesticide residues. Also, temporary flooding of soil or certain dredged material disposal methods can alter the physicochemical properties of contaminated soils or sediments affecting the persistence and possibly the mobility of pesticide residues. Information on the effects of physicochemical conditions on the adsorption and degradation of specific pesticides should contribute to improved predictive capability of the transport and fate of pesticide residues in various compartments of the environment.

ACKNOWLEDGMENTS

Credits. This research was sponsored by the Environmental Research Laboratory, U. S. EPA, Athens, Ga. (Grant #R804940-01-1).

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